

Feeding responses of red-winged blackbirds to multisensory repellents

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The concept that combinations of aversive stimuli are more repellent than the individual components is familiar but has been subject to little critical experimentation. In this study, we evaluated the effectiveness of aural (alarm call), visual (red dye), and chemical (methyl anthranilate and methiocarb) stimuli for reducing consumption of brown rice by captive red-winged blackbirds (*Agelaius phoeniceus*). The species-specific alarm call was ineffective, as was red dye beyond an initial neophobic response. Of the stimulus combinations tested, only 0.005% (g/g) methiocarb plus red plus methyl anthranilate proved more effective than the most effective individual component stimulus. The 0.025% methiocarb and 0.025% methiocarb plus methyl anthranilate treatments suppressed consumption effectively and also caused subsequent presentation of untreated brown rice to be avoided. Our findings suggest that for repellent applications to seeded crops and ripening grains the use rate of an illness-inducing agent such as methiocarb can be substantially reduced if paired with a deterrent colour and a chemical irritant.

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Throughout North America, red-winged blackbirds (*Agelaius phoeniceus*) cause substantial damage to rice, corn, and other crops (Besser and Brady, 1986; Decker, Avery and Way 1990; Hothem, DeHaven and Fairaizl, 1988). One technique for reducing damage by blackbirds and other species is application of chemical repellents (Holler *et al.*, 1985; Mason and Clark, 1992). However, concern over the potentially toxic effects of pesticides has limited the availability of bird repellent chemicals (Tobin and Dolbeer, 1988). One obvious approach to reduce chemical residues is to lower repellent application rates; however, such reductions can negatively affect efficacy (Avery *et al.*, 1993). One strategy for maintaining effectiveness at reduced application rates may be the use of stimulus combinations (Mason, 1989). Such combinations might include repellents that operate via gastrointestinal malaise (e.g. methiocarb), repellents that operate via sensory pain (e.g. methyl anthranilate), aposematic colours (e.g. red, orange), and aversive auditory stimuli (e.g. alarm calls). Ideally, chemical stimuli would be included at concentrations below those that normally produce avoidance, the notion being that additivity or synergy among the components would increase total effectiveness.

Feeding deterrents are designed to suppress consumption. To do so most effectively, it is essential to exploit the sensory capabilities of the target species. There is little evidence, however, that multiple stimuli reduce consumption more effectively than the individual components. Most studies on this topic have emphasized 'cue-enhanced' repellency (e.g. Bullard, Bruggers and Kilburn, 1983; Elmahdi, Bullard and Jackson, 1985) in which a sensory cue (usually visual) is paired with an aversive chemical agent to enhance the repellency of the chemical. Typically, such studies report that birds are better able to discriminate between untreated food and food treated with the chemical repellent plus sensory cue, but total food consumption is not reduced.

One exception was a study by Mason (1989), in which the combined and individual effects of methiocarb, methyl, anthranilate, and a white visual cue (calcium carbonate) were examined. Both of the chemical repellents were presented at marginally effective concentrations. The results showed that methiocarb/methyl anthranilate and methiocarb/calcium carbonate mixtures were more effective than methiocarb alone. Likewise, Avery and Nelms (1990) found that an effective concentration of methiocarb on brown rice (0.125%, Holler *et al.*, 1985) was even more effective when presentations were paired with colour, taste, and/or odour stimuli.

The objective of the present set of experiments was to investigate the repellency of various combinations of

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visual, auditory, and chemical stimuli. Reduction in food consumption was selected as the measure of effectiveness because feeding is easily quantified and relevant to a variety of management applications. Furthermore, by challenging birds with one-cup feeding trials, we evaluated the actual deterrent effect of the treatments rather than the birds' ability to discriminate between treated and untreated food.

Materials and methods

We maintained wild-caught male red-winged blackbirds (*Agelaius phoeniceus*) in group cages (1.3 × 1.3 × 1.8 m) in an outdoor aviary for 2–3 months before testing. Birds had free access to F-R-M® Game Bird Starter and water. Four days before the initial test day, we transferred birds from group cages to individual (45 × 45 × 45 cm) test cages in another outdoor aviary. Following the test, we banded and released all birds.

On each treatment and post-treatment day, we gave each bird 25 g of brown rice in a clear plastic cup. Aluminum pans suspended beneath the cups caught spillage. We placed other cups, one holding each rice treatment, not exposed to birds, near test cages to record moisture gain or loss.

There were five experimental stimuli: a red-winged blackbird alarm call, water-soluble commercial red food colouring, 0.5% (g/g) methyl anthranilate, 0.005% methiocarb, and 0.025% methiocarb. For the alarm call, five 20-sec series of taped alarm calls, interspersed with 100 sec of silence, were broadcast at 6-min intervals during the daily treatment period. For the visual cue, we thoroughly mixed 5 ml of water-soluble commercial red food colouring in 250 g of brown rice. For methyl anthranilate (MA), we combined 11 ml of technical chemical with 3.2 ml of propylene glycol and thoroughly mixed this solution with 250 g of brown rice. This produced a treatment rate of 0.5% MA, a level previously shown to suppress feeding of red-winged blackbirds (Mason *et al.*, 1991). For methiocarb, a post-ingestive chemical agent, we dissolved Mesurol® 75% WP (Bayer Corp., Kansas City, KS) in 3.2 ml of propylene glycol and thoroughly mixed this solution with 250 g of brown rice. We tested two levels of methiocarb, 0.005% and 0.025% (g/g), that were considerably lower than the rate (0.125%) used previously to suppress feeding by redwings on brown rice (Avery and Nelms, 1990). Control groups received brown rice that had been mixed in 250-g batches with 3.2 ml of propylene glycol. All brown rice was air-dried 24 hours before being used.

We conducted four separate experiments (Table 1), each involving different birds. After the 3-day treatment period, there was a 2-day break followed by a 3-day post-treatment period, during which only plain brown rice was offered. We estimated each bird's daily consumption by weighing the contents of the food cup and correcting for spillage and moisture gain or loss.

In Experiment 1, groups of eight birds received one of four brown rice treatments: plain, MA, red, or MA/red. During the treatment phase, four birds in each group were exposed to the alarm call tape while four were not exposed to the tape. We videotaped selected birds to observe feeding behaviour while the alarm call

was playing. Experiment 2 was similar to Experiment 1 except that the daily test period was 3 hours instead of 1 hour.

No alarm call was used in Experiments 3 and 4. Instead, we tested methiocarb, alone and in combination with MA and red dye. In Experiment 3, we applied 0.025% methiocarb, and then lowered the rate to 0.005% in Experiment 4. The daily test period was 3 hours and there were eight birds/treatment. The post-

Table 1. Experimental design used in evaluation of multi-sensory avian feeding deterrents

Parameter	Experiment			
	1	2	3	4
Repellent stimulus				
Alarm call	X	X		
Red dye	X	X	X	X
Methyl anthranilate	X	X	X	X
Methiocarb 0.025%			X	
Methiocarb 0.005%				X
Number of treatment groups	8	8	5	5
Birds/treatment group	4	4	7	7
Daily test period (h)	1	3	3	3
Duration of treatment phase (days)	3	3	3	3
Duration of post-treatment (days)	3	3	5	3

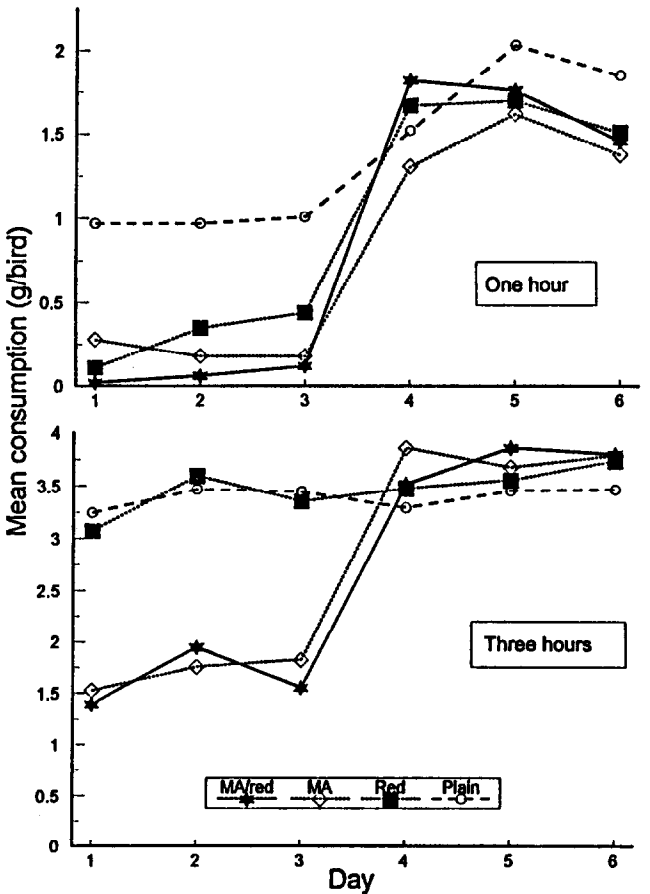


Figure 1. Mean daily consumption of brown rice by individually caged male red-winged blackbirds during 1-hour and 3-hour feeding trials. During the treatment period (days 1–3), each bird received one cup of 25 g of brown rice that was either untreated, treated with 0.5% (g/g) methyl anthranilate (MA), red food colouring, or a combination of MA and red. During the post-treatment period (days 4–6), all birds received plain brown rice

treatment period of Experiment 3 was extended to 5 days to examine more closely the birds' recovery from the treatments.

Analyses

We conducted repeated measures analyses of variance on consumption data for each trial separately, with treatment as the independent factor and repeated measures across period (treatment, post-treatment). We used *t*-tests to assess differences between the number of visits to the food cup during alarm calls and periods of silence. To evaluate the effectiveness of the various stimuli and their combined effects across trials, we calculated relative consumption scores by dividing the daily mean of each treatment group by the mean consumption of the respective control groups. We used the Tukey HSD test (Steel and Torrie, 1980) to identify significant differences among means ($P > 0.05$).

Results

Experiment 1 – 1-hour test with alarm calls

The red-winged blackbird alarm call did not affect consumption by itself ($P = 0.613$) or in interactions

with other stimuli ($P > 0.140$). Furthermore, videotapes of two birds showed no difference ($P > 0.25$) in the number of visits to the food cup with the taped alarm call playing and with it silent. We thus eliminated alarm call as a factor in further analyses.

Total rice consumption varied ($F = 3.85$, d.f. = 3,28, $P = 0.02$) among treatment groups, being less for birds exposed to MA and MA/red than for those in the red and control groups. Consumption across all groups was less ($F = 381.9$, d.f. = 1,156, $P < 0.001$) in the treatment period ($m = 0.39$ g bird⁻¹, SE = 0.07) than during post-treatment ($m = 1.64$ g bird⁻¹, SE = 0.05). The two-way interaction ($F = 6.72$, d.f. = 3,156, $P < 0.001$) reflected relatively higher consumption by the control group during the treatment period (days 1–3, Figure 1); during post-treatment (days 4–6), there were no differences among groups.

Experiment 2 – 3-hour test with alarm call

During the 3-hour feeding trial, birds exposed to the alarm call consumed as much ($P = 0.719$) as those not exposed to the call. There was no interaction ($P = 0.623$) between test period and the sound stimulus. We thus eliminated alarm call from further analyses.

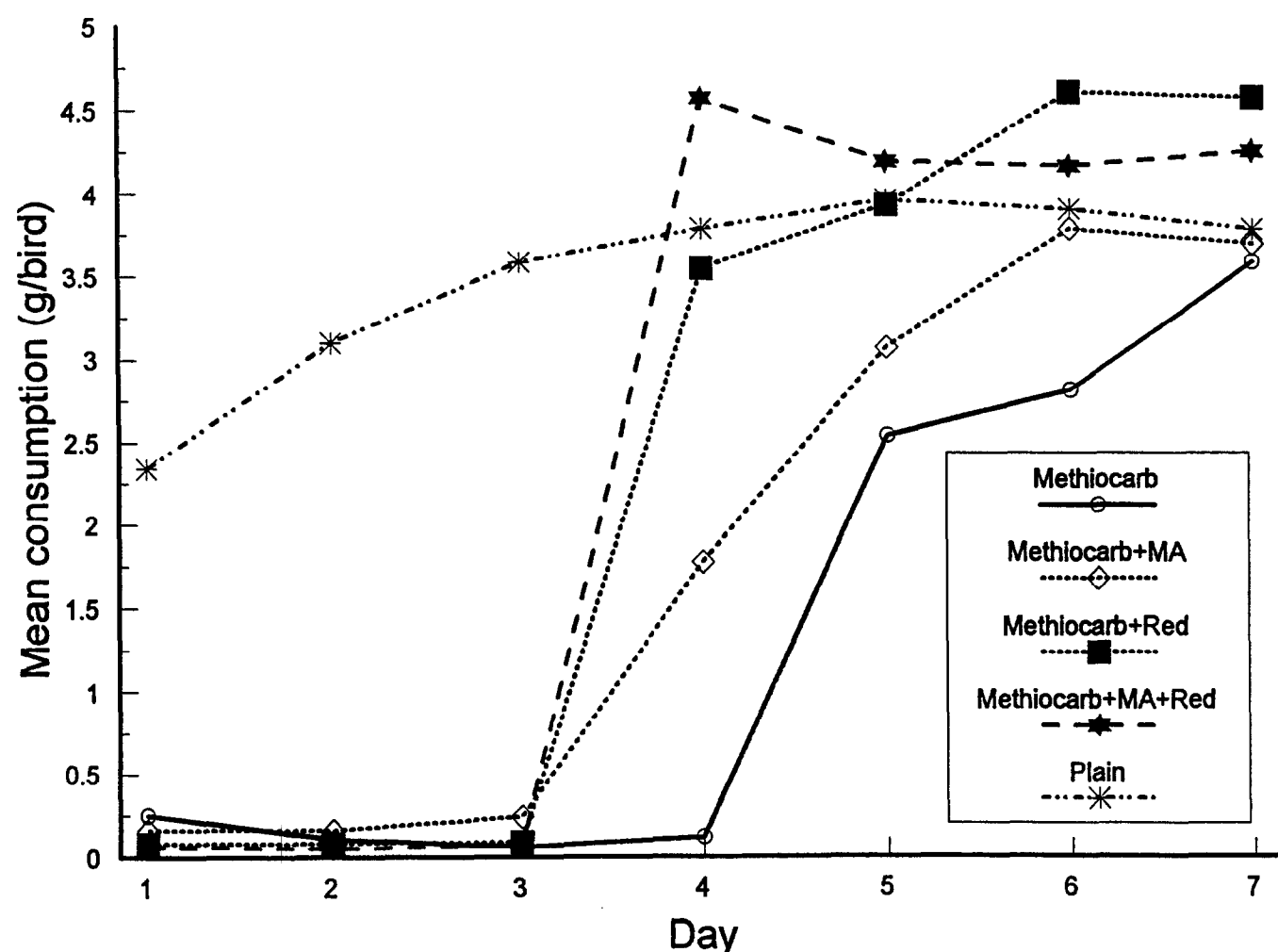


Figure 2. Mean daily consumption of brown rice by individually caged male red-winged blackbirds during 3-hour feeding trials involving methiocarb (0.025% g/g), methyl anthranilate (MA, 0.5% g/g), and red food colouring. During the treatment period (days 1–3), each bird received one cup of 25 g of brown rice with the indicated treatment ($n = 7$ birds group⁻¹). During post-treatment (days 4–7), only plain brown rice was offered

Over the 6-day trial, brown rice consumption varied among stimulus groups ($F = 6.01$, d.f. = 3,28, $P = 0.003$). Consumption by birds exposed to MA (2.75 g bird^{-1} , SE = 0.14) and MA/red (2.68 g bird^{-1} , SE = 0.15) was less than by those given red (3.47 g bird^{-1} , SE = 0.09) and control (3.40 g bird^{-1} , SE = 0.04). Across all groups, consumption during the treatment period (2.52 g bird^{-1} , SE = 0.09) was less ($F = 203.9$, d.f. = 1,348, $P < 0.001$) than during post-treatment (3.63 g bird^{-1} , SE = 0.05). The interaction ($F = 53.17$, d.f. = 3,348, $P < 0.001$) reflected the suppressed consumption during the treatment period by birds in the MA and MA/red groups relative to those in the red and control groups (Figure 1).

Experiment 3 – methiocarb (0.025% g/f) plus MA and red

Across the 7-day trial, consumption by each group was suppressed ($F = 12.55$, d.f. = 4,30, $P < 0.001$) relative to the control group ($m = 3.49 \text{ g bird}^{-1}$, SE = 0.12). Consumption by the methiocarb-only group was significantly lower (1.35 g bird^{-1} , SE = 0.25) than all others except for the methiocarb/MA group (1.84 g bird^{-1} , SE = 0.29).

Mean consumption across all groups varied ($F = 129.09$, d.f. = 6,180, $P < 0.001$) among days. Consumption on each of the three treatment days was significantly less than that on day 4, the first post-treatment day, which in turn was less than that on post-treatment days 5–7.

The treatment \times day interaction ($F = 8.84$, d.f. = 24,180, $P < 0.001$) reflected varying patterns of consumption across days (Figure 2). During the treatment period (days 1–3), consumption by all groups was significantly suppressed relative to the control group. During post-treatment days 5–7 there were no differences among groups. On day 4, however, the first post-treatment day, consumption by the methiocarb and methiocarb/MA groups was significantly less than that of the controls and other treatment groups. Furthermore, mean consumption by the methiocarb/MA group did not equal the controls until day 6, while the methiocarb group reached mean control level consumption on day 7 (Figure 2).

Experiment 4 – methiocarb (0.005% g/g) plus MA and red

Consumption varied ($F = 4.94$, d.f. = 4,30, $P = 0.004$) among groups, and all except the methiocarb/MA group exhibited lower consumption across treatment and post-treatment periods than did the control group. Across all groups, consumption differed ($F = 82.25$, d.f. = 5,150, $P < 0.001$) among days, being lower during treatment than during post-treatment.

The interaction ($F = 5.63$, d.f. = 20,150, $P < 0.001$) between treatment and day showed that, relative to the control group, consumption by treatment groups was suppressed on days 1–3, but not on days 4–6 (Figure 3). Although consumption by the methiocarb/MA/red group appeared to be suppressed more than the other groups on days 1–3, the difference was not statistically distinct ($P > 0.05$).

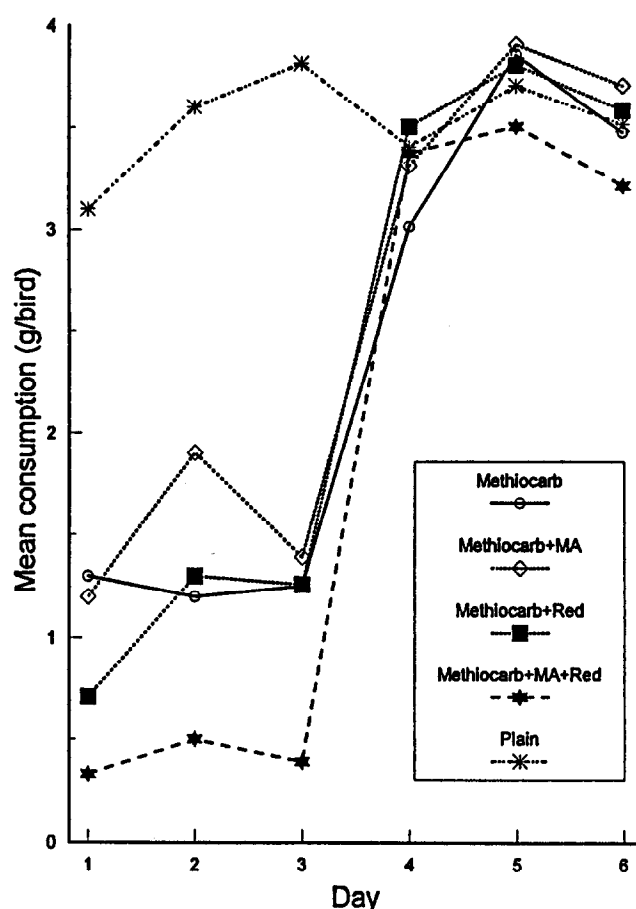


Figure 3. Main daily consumption of brown rice by individually caged male red-winged blackbirds during 3-hour feeding trials involving methiocarb (0.005% g/g), methyl anthranilate (MA, 0.5% g/g), and red food colouring. During the treatment period (days 1–3) each bird received one cup of 25 g brown rice with the assigned treatment ($n = 7$ birds group $^{-1}$). During post-treatment (days 4–6), only plain brown rice was offered

Comparison among experiments

Relative scores ranged from 0.02 (near total suppression) for the 0.025% methiocarb/MA/red groups to 0.95 (near absence of suppression) for the alarm call/red group (Figure 4). The scores fell into distinct clusters. The 0.025% methiocarb treatment groups and the 0.005% methiocarb/MA/red group were the most effectively suppressed whilst the alarm, red, and alarm/red treatments proved least effective.

Because of the strong reduction in consumption (relative consumption score of 0.06) due to 0.025% methiocarb alone, there was scant opportunity for additional deterrence through the addition of sensory stimuli. The 0.005% methiocarb/red/MA (0.11) treatment, however, suppressed feeding below ($P < 0.05$) that of the most effective single component, 0.005% methiocarb (0.36). The other combinations performed no better ($P > 0.05$) than their most effective individual components.

Discussion

During post-treatment, when only plain brown rice was available, the 0.025% methiocarb and 0.025%

methiocarb/MA treatments continued to suppress consumption (Figure 2). We suspect that the strong post-ingestive effect of 0.025% methiocarb and the visual similarity of the brown rice in the treatment and post-treatment periods facilitated generalization of this avoidance response. We believe, therefore, that there are occasions where coloured formulations for avian crop protection chemicals may be unnecessary (Greig-Smith, 1987) and might even weaken avoidance as the colour could provide birds with a cue to discriminate treated from untreated crops. If residual protection is desired, the important factor seems to be the degree of similarity between the treated and untreated food items (Avery, 1980), rather than the use of aposematic colour *per se*.

Mason (1989) suggested that anthranilate repellency might be improved by the addition of a distinctive colour. We found no evidence of such an interaction, however. Similarly, in feeding trials with European starlings (*Sturnus vulgaris*), the presence of a distinctive visual stimulus did not enhance repellency of anthranilate treatment (Avery and Matteson, 1995).

Aversive chemical stimuli such as MA or chemical stimulus/visual cue combinations might permit reduced

levels of post-ingestive chemical repellent application in the field (Mason, 1989). Our findings partially support this as the repellency of 0.005% methiocarb when paired with MA/red was equal to that of the 0.025% methiocarb treatments. However, the effectiveness of 0.005% was not improved by MA alone.

Residual repellency and enhanced immediate repellency may be mutually exclusive. For enhanced repellency to be demonstrated, the aversive post-ingestive agent must by definition be at less than maximal rate. When such reduced rates are used, however, there appears to be no carry-over repellency. The later is achieved by increasing the treatment rate of the post-ingestive chemical agent, but at such high rates further suppression of consumption may be impractical. In this study, we did not explore the use of colour during the post-treatment phase. There is abundant prior evidence, however, that birds can learn to avoid colours that have been paired with sickness (Avery and Nelms, 1990; Greig-Smith and Rowney, 1987; Mason and Reidinger, 1983).

Practical use of our findings will principally be in reducing avian depredations to seed crops or ripening grains that can be treated with a post-ingestive agent/sensory repellent combination. The most effective application should involve both visual deterrent and chemical irritant components as we found that neither the red dye nor MA alone was consistently associated with lowered consumption of methiocarb-treated brown rice.

Identification of the most appropriate combination of stimuli for a given bird damage application will require laboratory and field testing to determine efficacious treatment rates. Feeding trials with captive birds are needed to screen numerous possible treatments rapidly and efficiently. The test species in laboratory trials should include the major target species of concern in the field. After candidate treatments are identified, replicated field trials will be performed to verify the laboratory findings. The practical value of a proposed bird repellent treatment will depend on the grower's expected level of bird damage and the value of the damaged crop.

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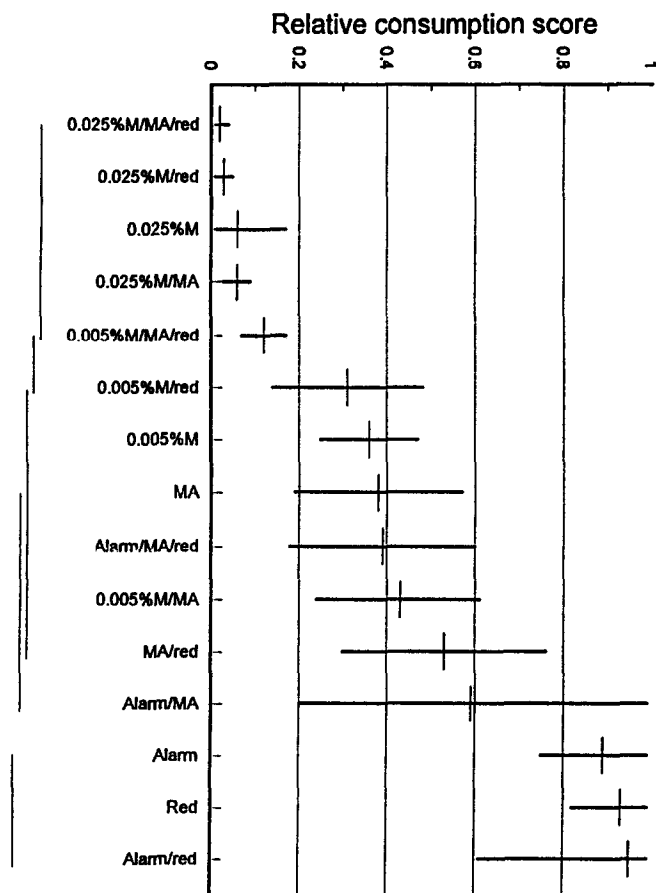


Figure 4. Relative brown rice consumption scores of red-winged blackbirds exposed to various treatments during 3-hour feeding trials. Scores were derived by dividing each bird's daily consumption by the mean consumption of the control group in that trial. Means for the 3-day treatment period were calculated and plotted with the 95% confidence intervals. Lower scores indicate greater suppression of feeding. Groups joined by vertical lines at the left of the figure are not statistically different ($P < 0.05$).

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